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A novel strategy for markedly enhancing the red upconversion emission in Er^{3+}/Tm^{3+} cooperated nanoparticles

Jiating Xu,‡ Dan Yang,‡ Wei Han, Shuming Dong, Tao Jia, Fei He,* Huiting Bi, Shili Gai, Li Li, Piaoping Yang*

Key Laboratory of Superlight Materials and Surface Technology, Ministry of Education, College of Material Sciences and Chemical Engineering, Harbin Engineering University, Harbin, 150001, P. R. China

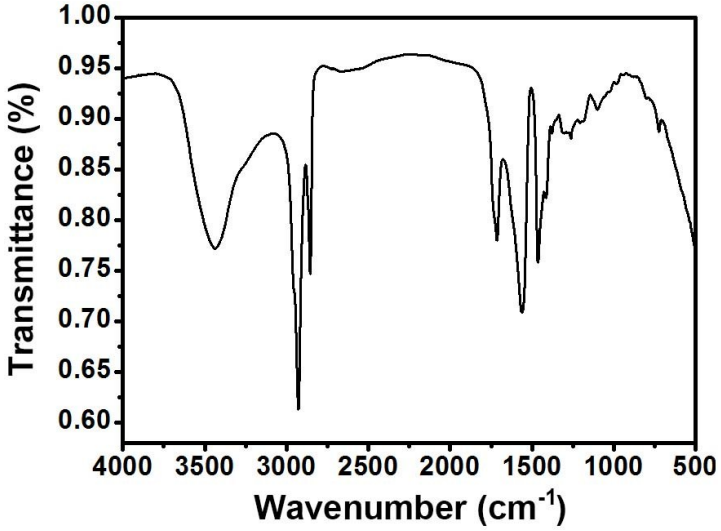

Fig. S1 FT-IR spectrum of the prepared $NaErF_4$:Tm@$NaErF_4$:Yb nanoparticles.

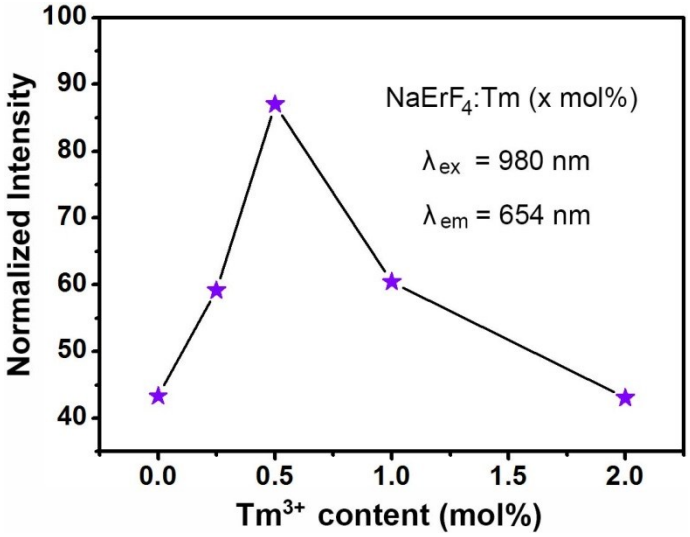

Fig. S2 Normalized upconversion emission intensity of $NaErF_4$:Tm core nanoparticles with different Tm^{3+} doping content under 980 nm laser excitation.

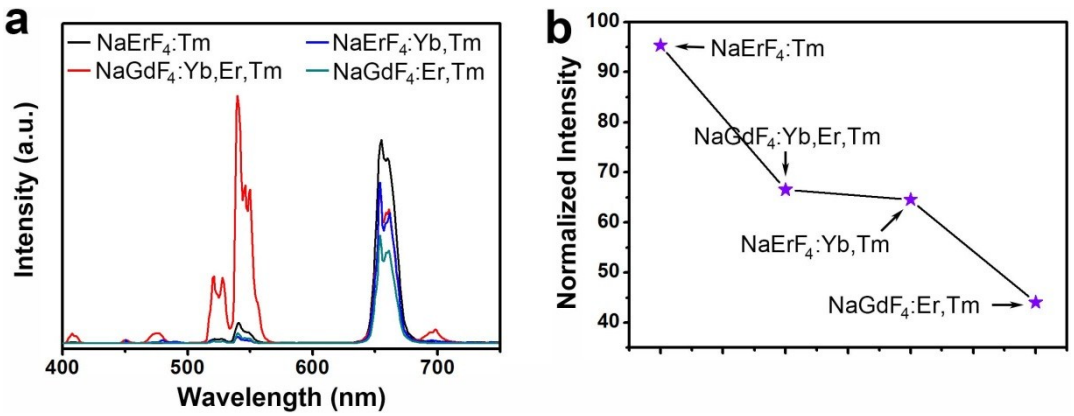

Fig. S3 Upconversion emission spectra (a) and the normalized emission intensity in red region (b) of $NaErF_4$:0.5%Tm, $NaGdF_4$:18%Yb,2%Er,0.5%Tm, $NaErF_4$:18%Yb, 0.5%Tm and $NaGdF_4$:2%Er,0.5%Tm nanoparticles (a) under 980 nm laser excitation.

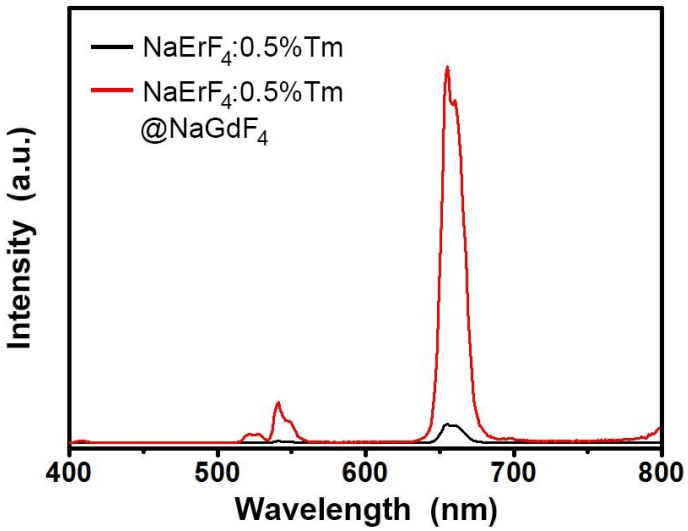

Fig. S4 Upconversion emission spectra of the $NaErF_4$:0.5%Tm core-only and $NaErF_4$:0.5%Tm@$NaGdF_4$ core-inert shell nanoparticles.

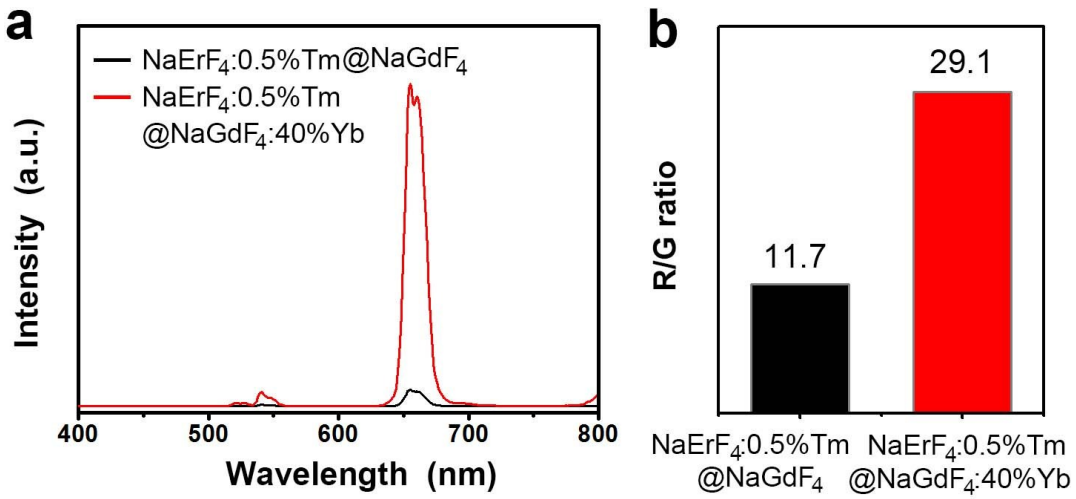

Fig. S5 Upconversion emission spectra (a) and the R/G ratio (b) of the $NaErF_4$:0.5%Tm@$NaGdF_4$ and $NaErF_4$:0.5%Tm@$NaGdF_4$:40%Yb nanoparticles.

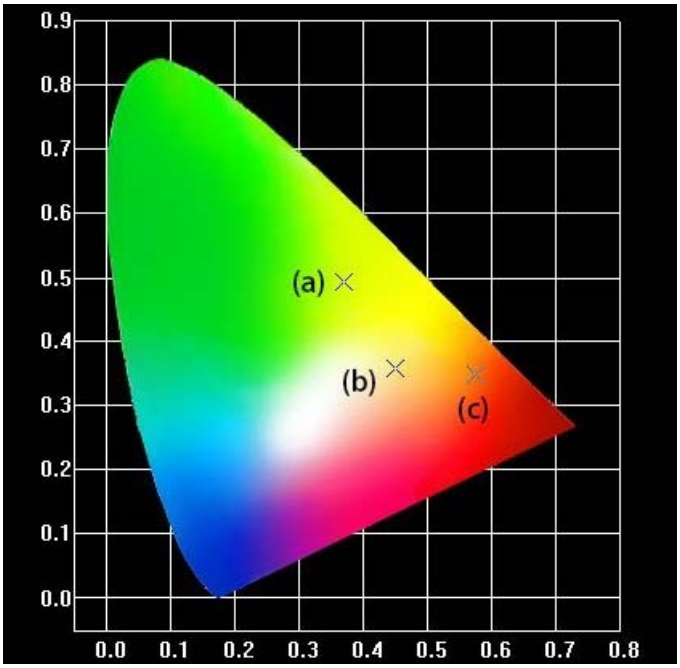

Fig. S6 CIE chromaticity diagram of $NaErF_4$ (a), $NaErF_4$:0.5%Tm core nanoparticles (b) and $NaErF_4$: 0.5%Tm@$NaGdF_4$:40%Yb (c) core-active shell nanoparticles.

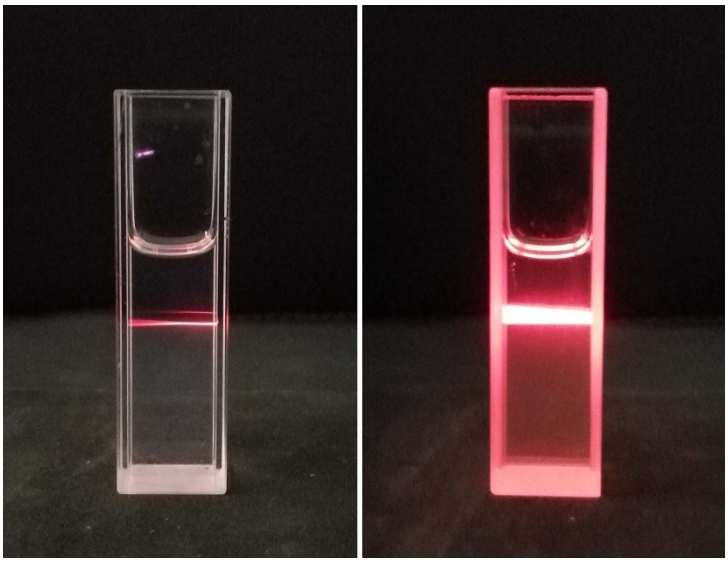

Fig. S7 Photographs of $NaErF_4$:0.5%Tm core-only nanoparticles (left side) and $NaErF_4$:0.5%Tm@$NaGdF_4$:40%Yb core-active shell nanoparticles (right side) when dispersed in cyclohexane and radiated by 980 nm laser (note: the two solutions are at identical concentrations).

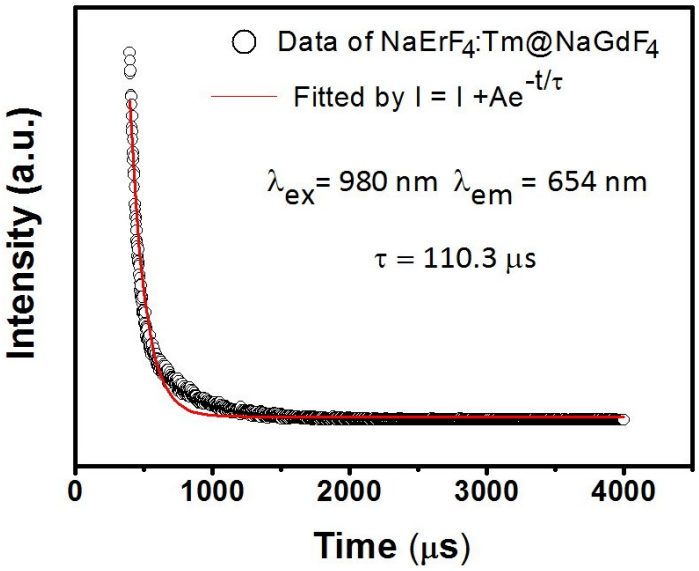

Fig. S8 Decay curve of Er^{3+} at 654 nm in $NaErF_4$:0.5%Tm@$NaGdF_4$ core-inert shell nanopareticles under 980 nm laser excitation.

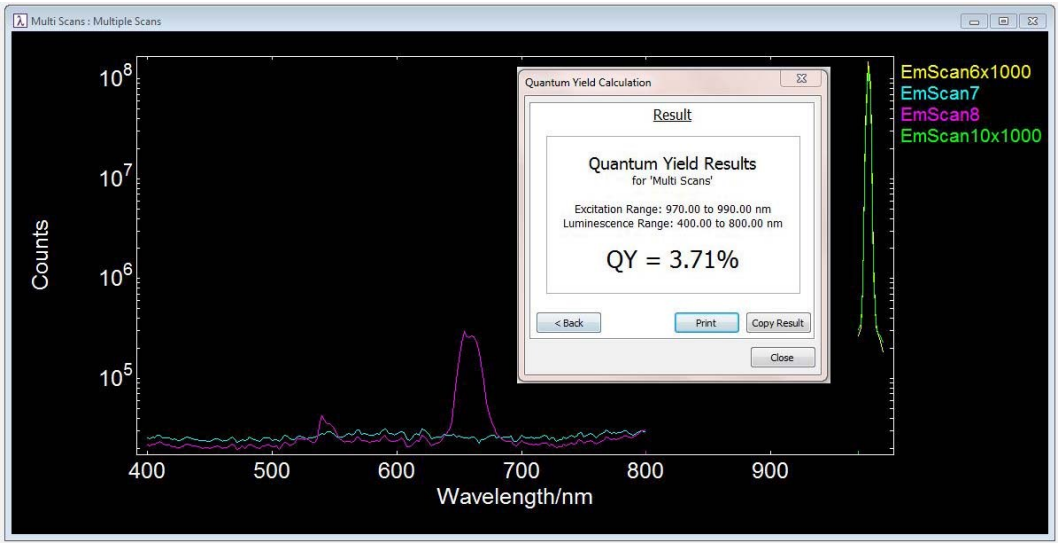

Fig. S9 Quantum yield measurement of $NaErF_4$:0.5%Tm@$NaGdF_4$:40%Yb core-active shell nanoparticles.